AT a meeting of the Royal Scottish Geographical Society, held last week at Edinburgh, with Prof. J. Geikie in the chair, to consider the question of Antarctic research, the following resolution by the council of the Society was read:—"That at this meeting, held for the discussion of Antarctic research, the Royal Scottish Geographical Society resolves to give its hearty support to the promotion of further exploration in the Antarctic. The Society's council is of opinion that at the present time a properly equipped Government expedition would, with the increased advantages of steam and modern appliances, have every prospect of successful explorations in the South Polar regions. The council is also convinced that the additions which might be made to our knowledge of climatology, terrestrial magnetism, geology, and natural history, would be of such practical scientific value as to fully justify the equipment of such an expedition at national expense. Towards the promotion of this object the council considers it desirable to submit a memorial on this subject to her Majesty's Government, and in this action they invite the cooperation of all the leading scientific societies of Scotland. To this end the Society appoints an Antarctic committee, consisting of Dr. John Murray, Prof. James Geikie, Dr. Buchan, and Mr. J. G. Bartholomew, together with the delegates of the other scientific societies, with instructions to draft such a memorial and take such steps towards the promotion of Antarctic exploration as is deemed desirable." A committee of the Royal Geographical Society was formed on the occasion of Dr. Murray's paper (NATURE, vol. xlix. p. 112), and has already been at work for some time with a view to bring the whole question of Antarctic exploration before Government. The course of action of this committee we understand to be the memorialisation of the Royal Society, requesting that body to take the lead in approaching the Government after ascertaining the feeling of all the leading scientific societies of the United Kingdom.

THE RISE OF THE MAMMALIA IN NORTH AMERICA.[1]

II.

Primitive Trituberculism.

There is a very general tendency among the vertebrates as a whole, fishes and reptiles as well as mammals, to form what are called "triconodont" crowns by the addition of lateral cusps to simple cones. In the mammals alone, these three cusps pass into higher stages of evolution, through what is called "trituberculy," in which these cusps form a triangle. The discovery of primitive widespread trituberculy by Cope was a great step forward. In looking over the odontographies of Cuvier, Owen, Tomes, and Baume, we find there is no suspicion of this common type around which the highly diverse mammalian molars centre. The molars of the clawed and hoofed mammals can now be compared, as we compare the hand or foot of the horse with that of the cat, because they spring from a common type. All the specialised mammalian series—ungulates, primates, carnivores, insectivores, rodents, marsupials—are found playing similar yet independent adaptive variations upon one type. We thus have a clue to the comparison of all molars with each other and with the reptile cones; take the human grinders, for example. The anterior outer cusps in the upper jaw, and the anterior inner cusps in the lower jaw, are homologous with each other and with the reptilian cone. Leaving aside for the moment Multituberculates and Monotremes, every known triassic, jurassic, cretaceous and basal eocene mammal (excepting Dicrocynodon) is in some stage of trituberculy; all the known cretaceous molars are simple triangles above; all later fossil mammals also converge to trituberculy, until in the lowest eocene every molar is tritubercular, and the early stages of divergence are so similar that it requires a practised eye to distinguish the molar of a monkey from that of a horse. Embryology supports the evidence of these fossil series. Thanks to the recent admirable researches of Röse and Tæcker, we find in the primates, ungulates and marsupials, that in the calcification of its dental caps every molar is heralded by *three cones placed in a triangle*, and in the lower jaw these three cones invariably appear in the same order (protocone, paracone, and metacone) in which they arose during the remote geological periods.

It is necessary to mention this overwhelming palæontological evidence, because "trituberculy" is still not universally recognised; Fleischmann and others have questioned the homologies of the upper and lower triangles, and two able writers, Röse and Forsyth Major, have independently proposed an opposition theory that "multituberculy" or "polybuny" is the mammalian archetype, the latter author believing trituberculy has become a "dogma." So far, however, from there being any decline of evidence, I am now able to add the Cretaceous mammalia to the tritubercular lists and bring forward evidence that the multitubercular molar instead of being primitive was derived from the tritubercular; moreover, all the researches I have been quoting tend to draw the mammals without exception into one of three great primary forms. The haplodont form, from which Dromotherium is just emerging in the Trias, is the oldest and nearest the reptiles; the triconodont, or three cones in line, was a predominating lower Jurassic type; the tritubercular, or three cones in a triangle (trigonodont, Rütimeyer), was the prevailing upper Jurassic and later form. The final predominance of the tritubercular over the others was due to its possibilities of mechanical adaptation to work of every kind—its *potential* in evolution. Upon the polyphyletic theory of the origin of the mammals here advocated, we must admit, first, the independent evolution of trituberculy in different phyla; and second, the branching off of several great groups in the pre-tritubercular stages.

The tendency of late research is to show that all stem mammals were related in their diphyodontism, in their dental formula, and in their primitive molar form. These features point, not to a succession, but to a unity of ancestry of the Monotremes, Marsupials, and Placentals.

Divergence of the Three Groups.

The discovery of the complete double series seems to have removed the last prop from the theory of the Marsupial ancestry of the placentals, for the peculiar mode of suppression of the second series in the Marsupials has been constant since the Purbeck; this difficulty is added to the structure of the jaw, the epipubic bones, the profoundly different mode of fœtal nutrition. None the less, any conclusion we can draw now as to the primary relations of the three great groups is more or less of a "Schwindelbau," and I put together the results of these later discoveries with a full realisation of the temporary character of present conclusions.

The Permian Sauro-Mammalia (Baur) with a multiple succession of simple conical teeth divided into: A, Theromorpha, which lost the succession and in some lines acquired a heterodont dentition and triconid single-fanged molars; B, Pro-mammalia.

The hypothetical lower Triassic Pro-mammalia retained a double succession of the teeth; they became heterodont, with incipient triconid double-fanged molars; dental formula approximating 4. 1. 4–5. 8. They gave rise to three groups: I. The Prototheria which passed rapidly through the tritubercular into the multitubercular molars in the line of Multituberculates, and more slowly into trituberculy and its later stages in the line of Monotremes. II. The Metatheria or Marsupials tended to suppress the second series of teeth, except those intercalated with the first; by this and by reduction the formula became 5. 1. 3. 4–6; the molars passed slowly through the triconodont into the typical tritubercular type. III. The Eutheria or Placentals divided early into a number of branches, in which there was heterodontism, but no uniform modification of succession.

We may distinguish four chief branches among these, as follows: (A) forms suppressing the second series in the molar region only, and acquiring a typical Eutherian dentition, 3. 1. 4. 3–4. 1. The Insectivores tended to partly suppress the anterior teeth of the second series or intercalate them with teeth of the first series; the molars became tritubercular. 2. The higher Placentals retained the succession of the first and second series as far back as the first molar; the molars entered rapidly into trituberculy and its higher stages. (B) forms retaining the double succession in part of the molar region, and retaining more of the primitive dentition, 4. 1. 4. 8. 3. The Edentates branched off from an early triconodont or tritubercular diphyodont stage, with numerous molars, and secondarily suppressed the first heterodont series, and established a numerous homodont second series. 4. The Cetacea also branched off from a diphyodont, heterodont stage, and secondarily established a numerous homodont first series, suppressing the second series.

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[1] Continued from p. 238.

Breaks and Links in the Mesozoic Fauna.

By our hypothesis all three sub-classes flourished together during the American Mesozoic; the Marsupials disappeared, then the Monotremes, and by the end of the basal Eocene the Placentals were in exclusive possession of the northern continent.

Although we have great reason to congratulate ourselves upon the rapid progress of discovery, there still remain great gaps in Mesozoic time between certain horizons, and in the lineal phyletic series of both the Mesozoic and Cenozoic. For a time standard we may take advantage of the remarkably constant evolution of the Plagiaulacidæ in the Mesozoic, and of the Equidæ in the Cenozoic—as certain invertebrates are made use of in older rocks. The grooves and tubercles of Plagiaulax and the cusps and styles of the horses are added with the precision of clockwork, and supposing that the rate of evolution has been about the same, we can approximately estimate both the periods of deposition and the intervals as follows.

PLAGIAULACIDÆ.

	Stonesfield.	Purbeck.	Laramie.	Puerco.	Cernaysian.
Number of Premolars,	?	4-3	2	2-1	1
Grooves on Premolars,	?	7-9	11-14	12-15	14
Molar Tubercles: outer; inner;	?	4:2	6:4	6:4	9:6

Estimating the geological intervals by dental evolution and faunal succession, there is first the great gap between the Trias of Microlestes and Dromatherium and the Jurassic of the Stonesfield slate; there is a relatively shorter interval, but still a considerable one between this and the Purbeck or Atlantosaurus beds. Then follows another long and very important interval between the Atlantosaurus beds and the Laramie (Upper Cretaceous). The gap between the Laramie and Puerco was relatively short, as indicated by the comparatively limited evolution both of the Plagiaulacids and Trituberculates. The Puerco was itself a long period in which the Plagiaulacids underwent considerable changes. Then follows an interval which it is most important to fill by future exploration, for between the Puerco and the Wahsatch the differentiation of the even and the odd-toed ungulates must have occurred. The Wahsatch proper does not mark a very extensive evolution of the forms it contains. It passes, after a slight break, into the base of the Bridger (Wind River), and then begins that splendid and almost uninterrupted succession of lake basins, terminating in the pliocene. I append a table, to be compared with that published by Marsh in his admirable address of 1877, and which exhibits the great progress of the last sixteen years.

THE SUCCESSION OF THE NORTH AMERICAN MAMMALIA.

PERIODS.	HORIZONS.	CHARACTERISTIC GENERA.	NEW TYPES APPEARING.	TYPES BECOMING EXTINCT.
Post or Upper **PLIOCENE.**	EQUUS.	*Equus*, 5 species. Elephant, E. *primigenius*. Mastodon. Llamas. Camels, *Eschatius*, *Holomeniscus*. Elk, *Alces*. *Platygonus*. Sloths, *Mylodon*, *Glyptodon*. *Ursus*.		
True PLIOCENE.	BLANCO.	*Equus*, 3 species. *Mastodon*, 3 sp. Llamas, *Pliauchenia*, *Platygonus*. Sloth, *Megalonyx*. *Felidæ*. (?) *Hyænidæ*. *Mustelidæ*.		
MIOCENE. Upper.	LOUP FORK.	*Protohippus*, *Hipparion*. *Mastodon*. Rhinoceroses, *Aphelops*, 5 species. *Canidæ*. *Felidæ*. Rodents. Edentates. Camels and Llamas, *Procamelus*, *Protolabis*. Oreodons, 3 genera. Deer, *Blastomeryx*, *Cosoryx*.		Extinction of Oreodons and hornless rhinoceroses.
	DEEP RIVER.	*Protohippus*, *Anchitherium*. First Mastodons. Oreodons, *Cyclopidius*. *Chalicotherium*. Tylopoda.		Disappearance of Chalicotherium. Extinction of Creodonts, Hyænodons.
Middle.	JOHN DAY. WHITE RIVER.	*Miohippus*. Two-horned Rhinoceros, *Diceratherium*. *Hyopotamus*. Peccaries. Oreodons. Rodents. *Canidæ*, *Felidæ*. Tylopoda.		Extinction of Elotheres and Hyopotamus
	PROTOCERAS. (Upper.)	(?) *Miohippus*. Artionyx.	Appearance of tragulines, Elotheres, *Hyopotamus*, pigs and peccaries, true dogs, cats, monkeys. *Leptauchenia*. *Colodon*. *Chalicotherium*, *Aceratherium*, *Protapirus*, *Agriochærus*. Opossums. Tylopoda, *Pöebrotherium*. Creodonts, *Hyænodon*. Rodents. Insectivores.	Extinction of Hyracodons.
Lower.	OREODON. (Middle.)	*Mesohippus*. Amynodon.		Extinction of Amynodons.
	TITANOTHERIUM. (Lower.)	*Mesohippus*. Titanotherium.		Extinction of Titanotheres.
EOCENE.	UINTA.	*Epihippus*. *Amynodon*. Titanothere, *Diplacodon*. First Oreodons, *Protoreodon*. First Tylopoda, *Leptotragulus*. Tapirs. Hyracodons. Rodents. Creodonts, *Mesonyx*.		
Upper.	BRIDGER. WASHAKIE. (Upper.)	*Pachynolophus*. Appearance of Amynodons and horned Titanotheres. *Palæosyops*. *Hyrachyus*. *Triplopus*. *Achænodon*.		Extinction of Dinocerata, of some Creodonts.
	BRIDGER. (Middle.)	*Pachynolophus*. Appearance of Insectivora, Cheiroptera, Hyracodons. *Uintatherium*. *Palæosyops*. Creodonts.		Extinction of Tillodontia.
Middle.	WIND RIVER. (Lower.)	*Hyracotherium*. *Palæosyops*. Dinocerata. *Coryphodon*. *Phenacodus*.		Extinction of Coryphodontia and Condylarthra.
	WAHSATCH.	*Hyracotherium*. Appearance of Artiodactyls, Perissodactyls: tapirs, horses, titanotheres, lophiodons. First Rodents. First Coryphodons, Lemurs and Monkeys. Creodonts, 6 families, *Palæonictis*.		Extinction of Arctocyons.
Lower.	Interval.	(*Differentiation of modern clawed and hoofed placentals.*)		
	PUERCO.	*Ptilodus*, *Neoplagiaulax*, *Polymastodon*. Ancient types of Ungulates, Carnivores and Insectivores: Amblypoda, Condylarthra, Creodonta. Tæniodonta. Tillodontia. Lemurs.		Extinction of Multituberculates (? Monotremes).
	Interval.	(*Differentiation of ancient clawed and hoofed placentals.*)		Disappearance of Marsupials.
UPPER CRETACEOUS.	LARAMIE.	*Ptilodus*. *Bolodontidæ* (Multituberculates). *Thlæodon*, Trituberculate Placentals and Marsupials. Typical dentition.		
	Interval.			
MIDDLE JURASSIC.	Atlantosaurus.	*Ctenacodon*, *Plagiaulax*, *Bolodon*, Multituberculates (? Monotremes). Triconodonts (? Marsupials). Trituberculates (? Placentals). Primitive dentition.		
	Interval.			
UPPER TRIASSIC.	Chatham Coal Beds.	*Protodonta*, *Dromotherium*, *Microconodon*, primitive Triconodonts (? Monotremes).		

The general faunal succession is marked by the sudden appearance and disappearance of certain series and rise and fall of great groups. In the Trias appears the remarkable protodont or primitive-toothed Dromotherium; we cannot determine its order at present. We still have no American fauna corresponding to the intermediate Stonesfield of England. In the Jurassic Atlantosaurus beds the three supposed representatives of the Monotremes (multituberculates), Marsupials (triconodonts), and Placentals (trituberculates), appear in equal numbers; the latter are generally characterised by the primitive dental formula. In the Laramie the Multituberculates continue in great profusion, and the Marsupials and Placentals are also numerous.

The serial succession of the Trituberculates from the Mesozoic is still an unknown chapter; we are utterly unable to connect the Dromatheriidæ of the Trias, the Triconodontidæ, Amphitheriidæ and Amblotheriidæ of the Jura with each other, or with any Cretaceous or lower tertiary mammals. The serial relations of the Multituberculates, on the other hand, have been made much clearer by the discovery of the Laramie fauna. Cope and Marsh in this country, and Smith Woodward in England, have at last broken into the long barren Cretaceous. In studying the accurate figures published by Marsh and a large collection of teeth recently made for the American Museum by Wortman and Peterson, I find that this Laramie fauna is widely separated from the Jurassic in its general evolution, and as Gaudry, Lemoine, and Cope have observed, it approaches more nearly the basal Eocene of the Puerco and the Cernaysian of France. The Multituberculates of the Laramie include the Plagiaulacidæ, represented by Ptilodus, the form with two premolars, and Meniscoëssus, with two premolars and crescentic tubercles. Meniscoëssus has a smaller fourth premolar, and is found to lead off to the huge plagiaulacid Polymastodon of the Puerco. The only other Multituberculates found are those related to Bolodon of the Jurassic and Chirox of the Puerco. The other mammals of the Laramie range from the mouse to the opossum in size; they have superior molars of the simple tritubercular type—the low cusped or bunodent molar predominating in the upper jaw, and the tuberculo-sectorial in the lower. The dental formula is mostly the typical p. 4, m. 3. Yet, judging by the angular region of the jaws, we have here both Placentals and Marsupials. Some of the teeth remind us strongly of those in the Puerco; their determination, however, is very difficult, for the jaws and teeth are almost entirely isolated. From another exposure of the Laramie, Cope has recently found the remarkable type Thlæodon—remarkable because it is a highly specialised trituberculate of typical dentition with a jaw which bears resemblance to that of the Multituberculates and of Ornithorhynchus. There is no placental angle nor strong marsupial inflection. This raises the supposition that Thlæodon may be one of the persistent trituberculate Monotremes which we are now looking for.

In the Puerco or basal Eocene, a very marked change occurs, for the American fauna loses some of its cosmopolitan character, the multituberculates or monotremes die out and the marsupials are not found at all; in fact they do not reappear in North America until the Miocene.

Ancient and Modern Placental Differentiation.

The Puerco is essentially an archaic fauna and is to be regarded as the climax of the first period of placental differentiation, a culmination of the first attempts of nature to establish insectivorous, carnivorous and herbivorous groups. These attempts began in the Cretaceous, and some of the types thus produced died out in the Puerco, some in the Wahsatch and Bridger; only a few flesh-eaters survived to the Miocene. It is most important to grasp clearly the idea of this functional radiation in all directions of this old Puerco fauna, resulting in forms like the modern insectivores, rodents, bears, dogs and cats, monkeys, sloths, bunodont and selenodont ungulates, and lophodont ungulates. This was an independent radiation of placentals, like the Australian radiation of marsupials. What was the cause of the wide-spread extinction of these types? So far as the ancient clawed types are concerned, their teeth and feet seem to be as fully adaptive in many cases as those of the later unguiculates; the hoofed types were certainly inferior in tooth evolution, for all their molars evolved on the triangular basis instead of the sexitubercular; the most sweeping defect of both the clawed and hoofed types was the apparent incapacity for brain-growth, their bodies went on developing while their brains stood still. Thus the stupid giant fauna, the Dinocerata, which rose out]o this period, gave way to the small but large-brained modern types. It is noteworthy that the latest survivors of this wreck of ancient life were the large-brained Hyænodons.

Some of the least specialised spurs of this radiation appear to have survived and become the centres of the second or mid-Tertiary radiation from which our modern fauna has evolved. Yet we have not in a single case succeeded in tracing the direct connection. To sum up, we find on the North American continent evidence of the rise and decline and disappearance of monotremes and marsupials, and two great periods of placental radiation, the *ancient radiation* beginning in the mesozoic, reaching a climax in the Puerco and unknown post-Puerco, and sending its spurs into the higher tertiary, and the *modern radiation* reaching its climax in the Miocene, and sending down to us our existing types.

Another Eocene centre was lower South America, which has of late dimmed the prestige of North America in yielding strange forms of life. One theory of this Patagonian fauna is that it was an independent centre of functional radiation like the Puerco and Australian, full of adaptive parallels, but not yielding to Europe or America any of their older types. But Ameghino, to whose energetic researches we are chiefly indebted, believes that he finds a lower Eocene life zone—a sort of *south polar* centre—which supplied both America and Europe. The Puerco he believes is no older than the Santacruzian, which in turn is very much older than the Parana and Pampean formations, which Burmeister has made so well known. This yields the *Homunculus Patagonicus* which parallels Cope's Anaptomorphus in presenting a dentition as advanced in reduction as that of man. Ameghino finds here the ancestors of the Macrauchenidæ; he believes the Homolodontotheridæ are the ancestors of the Chalicotheriidæ—thus deriving a buno-selenodont from a lophodont type; the Proterotheriidæ, he believes, replace the Condylarthra and Hyracotherium in the ancestry of the horses. Similarly the Microbiotheriidæ are the stem of the creodonts and carnivores. I cannot coincide with any of these views. The Multituberculates are far older and widely different from the Abderites to which Ameghino traces their ancestry. I fully concur with the opinion of Cope, Zittel, Scott and others that this fauna is of somewhat later age, that it was directly connected with Australia and somewhat later with North America, supplying us, as has always been supposed, with our sloths. I quote from a recent address by Scott:—

"The oldest mammals from South America are those from Patagonia, which Ameghino has referred to the Eocene, but which are more probably Oligocene or Miocene. This fauna is of extreme peculiarity and isolation; it is made up chiefly of edentates, rodents and ungulates of those very aberrant types known as Litopterna and Toxodontia, which are so widely different from the hoofed mammals of the northern hemisphere; together with some primitive forms of primates, creodonts and marsupials. The marsupials are of extraordinary interest, for they comprise not only forms allied to the opossums, but also to recent Australian forms such as Thylacinus, Dasyurus and Hypsiprymnus. This is a most unexpected fact, and seems to point unmistakably to a great southern circumpolar continent."

The Puerco thus remains the most extensively known and most productive lower Eocene centre, yet we have very slender threads of positive evidence to connect its fauna with the later placental radiation.

The Creodonts of Cope occupy the same relation to the modern insectivores and carnivores that the Condylarthra do to the ungulates. The American group has been recently enriched by the discoveries of Wortman, and the literature by the careful revision of Scott. This author has divided them into eight families, placing the forms which most resemble the Insectivora in the new family, Oxyclænidæ. These families illustrate superbly the same law of functional radiation later repeated in the placental and marsupial carnivores. The Mesonyx family presents some analogies to the Thylacines. The modern bears are paralleled in the Arctocyons, with their low tubercular molars; Wortman and myself, with fresh materials, have recently added Anacodon to this family, a genus which was doubtfully regarded by Cope as an ancient ungulate. The Cats and Hyænas are imitated in the Oxyænas and Hyænodons, some of the Miocene forms of which Scott suggests developed aquatic habits; as above noted, some of this family acquired large brains, and persisted late into the Miocene. A still more remarkable likeness to the cats is exhibited in the Palæonictis family, which, unlike the Hyænodons, forms its sectorials out of exactly the same teeth as the true cats. The first American Palæonictis was found two years ago by Wortman, and this author and myself have suggested that this may be the long-sought ancestor of the Felidæ. The Civets are anticipated in the Proviverridæ; yet both Cope and Scott, the highest authorities on this subject, believe that the dog-like Miacidæ alone formed the connecting link between the Creodonta and the true Carnivora.

The foot structure of the ancient Puerco ungulates is still only partly known. Cope has divided these animals into the Amblypoda and Condylarthra. The Amblypoda are represented in the Puerco by a large form called Pantolambda, with selenodont triangular upper molars, and possibly by Periptychus, with bunodont triangular molars. The Pantolambda molars were, as Cope has shown, converted into those of Coryphodon, the great lophodont Amblypod of the Wahsatch, by a process exactly analogous to that in which the *anterior* half of a Palæotherium molar was formed, that is, they acquired outer and anterior crests but no posterior crests. This Coryphodon molar type was still later converted into the Uintatherium type by swinging around the outer crest into a transverse crest. I have recently made a careful study of the fore and hind feet of Coryphodon, and have found that while the fore-foot was subdigitigrade like that of the elephant, the hind-foot was fully plantigrade, the entire sole resting upon the ground. The relation or connection between the Bridger Dinocerata and these earlier Amblypoda is still unknown. The Puerco Periptychus left no descendants. The other ungulates of the Puerco were the Condylarthra, the primitive Phenacodontidæ, the supposed ancestors of the Artiodactyls and Perissodactyls. Much remains to be done to clear up this question.

Thus an immense number of problems still await solution, and demand the generous co-operation of European and American specialists in the use of similar methods of research, in the prompt publication of descriptions and figures, and in the free use of museum collections. I may be pardoned for calling general attention to the service which the palæontological department of the American Museum is trying to render in the immediate publication of stratigraphical and descriptive tables of western horizons and localities.

The Factors of Evolution.

A few words in conclusion upon the impressions which a study of the rise of the mammalia gives as to the factors of organic evolution. I refer also to recent papers by Cope, Scott, and myself.

The evolution of a family like the Titanotheres presents an uninterrupted march in one direction. While apparently prosperous and attaining a great size, it was really passing into a great corral of inadaptation to the grasses which were introduced in the Middle Miocene. So with other families and lesser lines extinction came in at the end of a term of development and high specialisation. With other families no causes for extinction can be assigned, as in the lopping off of the smaller Miocene perissodactyls. The point is that a certain trend of development is taken leading to an adaptive or inadaptative final issue—but extinction or survival of the fittest seems to exert little influence *en route*.

The changes *en route* lead us to believe either in predestination—a kind of internal perfecting tendency—or in kinetogenesis. For the trend of evolution is not the happy resultant of many trials, but is heralded in structures of the same form all the world over and in age after age, by similar minute changes advancing irresistibly from inutility to utility. It is an absolutely definite and lawful progression. The infinite number of contemporary developing, degenerating, and stationary characters preclude the possibility of fortuity. There is some law introducing and regulating each of these variations, as in the variations of individual growth.

The limits of variation seem to lie partly in what I have called the "potential of evolution." As the oösperm or fertilised ovum is the potential adult, so the Eocene molar is the potential Miocene molar. We have seen that the variations of the horse and rhinoceros molars, apparently so diverse, are really uniform—is not this evidence that the perissodactyl stem had these variations *in potentia*, waiting to be called forth by certain stimuli? This capacity of similar development under certain stimuli is part of the law of mammalian evolution, but this does not decide the crucial point whether the reaction is spontaneous in the germ or inherited from the parent. I incline to the latter opinion.

H. F. OSBORN.

A DYNAMICAL THEORY OF THE ELECTRIC AND LUMINIFEROUS MEDIUM.[1]

I.

IT is only at the end of the last century that the somewhat vague principle of the economy of action or effort in physical actions—which, like all other general principles in the scientific explanation of nature, is ultimately traceable to a kind of metaphysical origin—has culminated in the hands of Lagrange in his magnificent mathematical generalisation of the dynamical laws of material systems. Before the date of this concise and all-embracing formulation of the laws of dynamics there was not available any engine of sufficient power and generality to allow of a thorough and exact exploration of the properties of an ultimate medium, of which the mechanism and mode of action are almost wholly concealed from view. The precise force of Lagrange's method, in its physical application, consists in its allowing us to ignore or leave out of account altogether the details of the mechanism, whatever it is, that is in operation in the phenomena under discussion; it makes everything depend on a single analytical function representing the distribution of energy in the medium in terms of suitable co-ordinates of position and of their velocities; from the location of this energy, its subsequent play and the dynamical phenomena involved in it are all deducible by straightforward mathematical analysis.

The problem of the correlation of the physical forces is thus divisible into two parts, (i.) the determination of the analytical function which represents the distribution of energy in the primordial medium which is assumed to be the ultimate seat of all phenomena; and (ii.) the discussion of what properties may be most conveniently and simply assigned to this medium, in order to describe the play of energy in it most vividly, in terms of the stock of notions which we have derived from the observation of that part of the interaction of natural forces which presents itself directly to our senses, and is formulated under the name of natural law. It may be held that the first part really involves in itself the solution of the whole problem; that the second part is rather of the nature of illustration and explanation, by comparison of the intangible primordial medium with other dynamical systems of which we can directly observe the phenomena.

The chief representative of exact physical speculation of the second of these types has been Lord Kelvin. In the older attempts of this kind the dynamical basis of theories of the constitution of the æther consisted usually in a play of forces, acting at a distance, between ultimate elements or molecules of the medium; from this we must, however, except the speculations of Greek philosophy and the continuous vortical theories of the school of Descartes, which were of necessity purely descriptive and imaginative, not built in a connected manner on any rational foundation. It has been in particular the aim of Lord Kelvin to deduce material phenomena from the play of inertia involved in the motion of a structureless primordial fluid; if this were achieved, it would reduce the duality, rather the many-sidedness, of physical phenomena to a simple unity of scheme; it would be the ultimate conceivable simplification. The celebrated vortex theory of matter makes the indestructible material atoms consist in vortex rings in a primordial fluid medium, structureless, homogeneous, and frictionless, and makes the forces between the atoms which form the groundwork of less fundamental theories consist in the actions excited by these vortices on one another through the inertia of the fluid which is their basis—actions which are instantaneously transmitted if the fluid is supposed to be absolutely incompressible.

In case this foundation proves insufficient, there is another idea of Lord Kelvin's by which it may be supplemented. The characteristic properties of radiation, which forms so prominent an element in actual phenomena, can be explained by the

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[1] A paper read before the Royal Society on December 7, 1893, by Dr. Joseph Larmor, F.R.S., Fellow of St. John's College, Cambridge.